High shares of renewables in Europe: relevant experience and lessons learned

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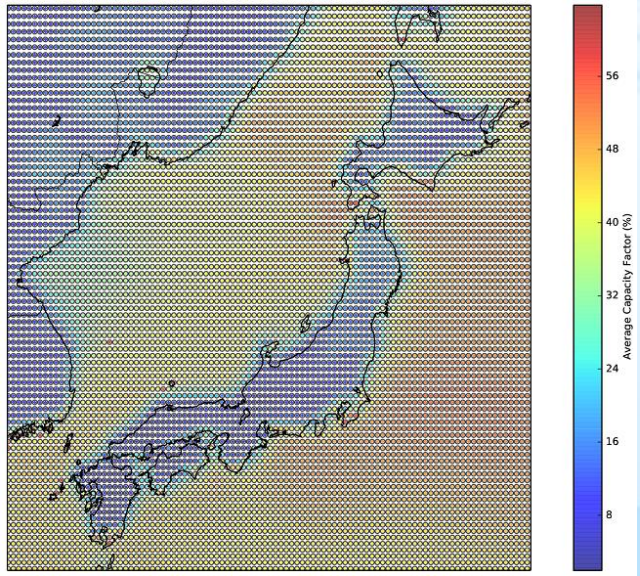

Source: Energynautics, based on National Centers for Environmental Prediction (NCEP) Climate Forecast System (CFS) Reanalysis data

Talk Overview

Individual European countries have reached shares of wind and solar in their electricity sectors of up to 40%.

Questions: How do we reach higher shares of renewables, given that wind and solar are variable?

Can a majority-renewable electricity supply be both secure and affordable?

(**Answer:** Grid capacity allows large areas to pool their renewable resources for the benefit of all.)

Agenda

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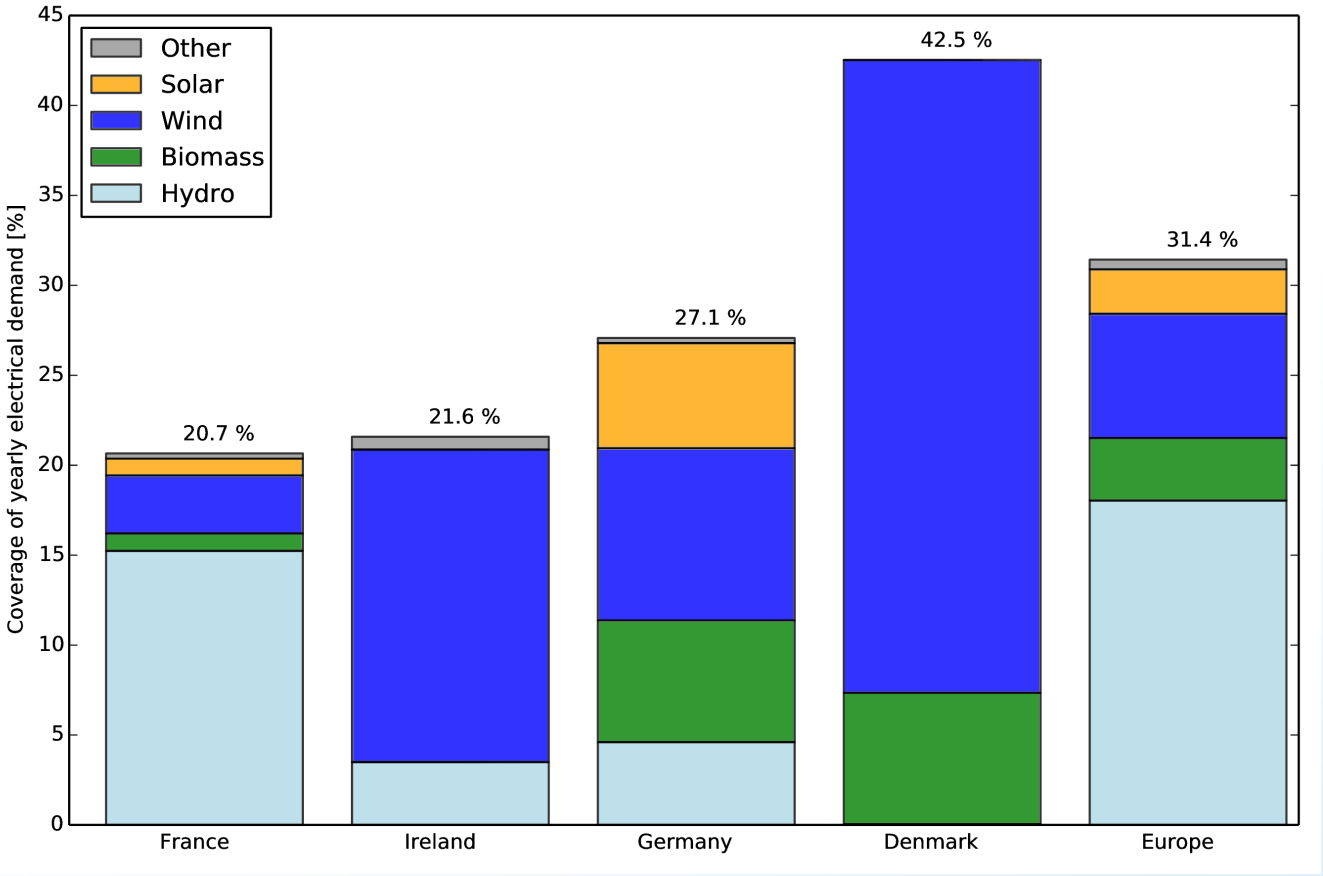
1. Current status of renewables in European countries

2. What it will take to get higher renewables share: a scenario with 77% electricity from renewables in Europe

3. Relevant experience for Japan

1. CURRENT STATUS OF RENEWABLES IN EUROPEAN COUNTRIES

Renewable Energy Generation in Europe in 2013



In 2014 provisional figures show:

- Germany reached nearly 30% RE coverage
- Denmark hit 39.1% from wind alone

Source: Energynautics, based on statistics from ENTSO-E Yearbook 2013

Germany: development of electricity mix since 1990

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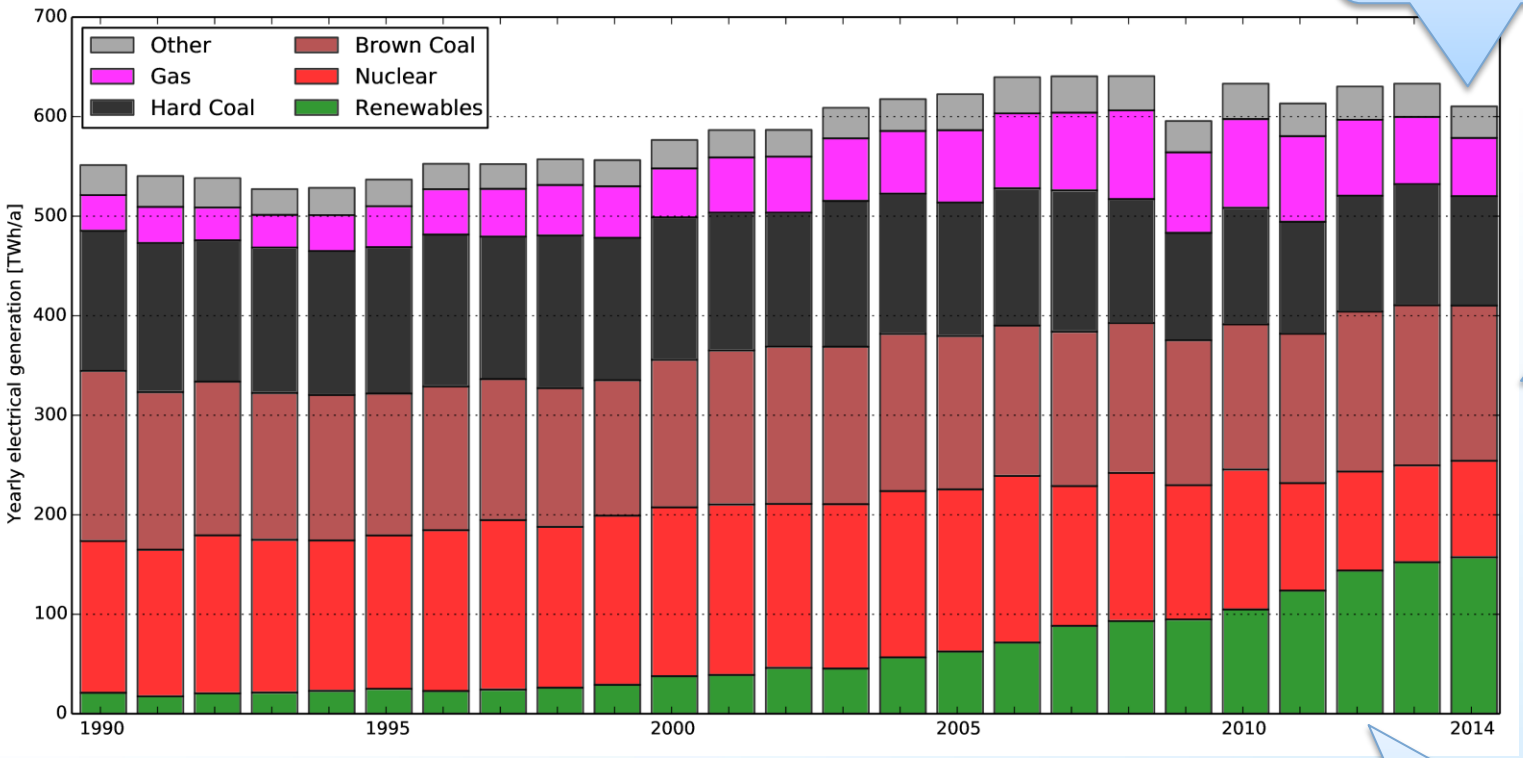


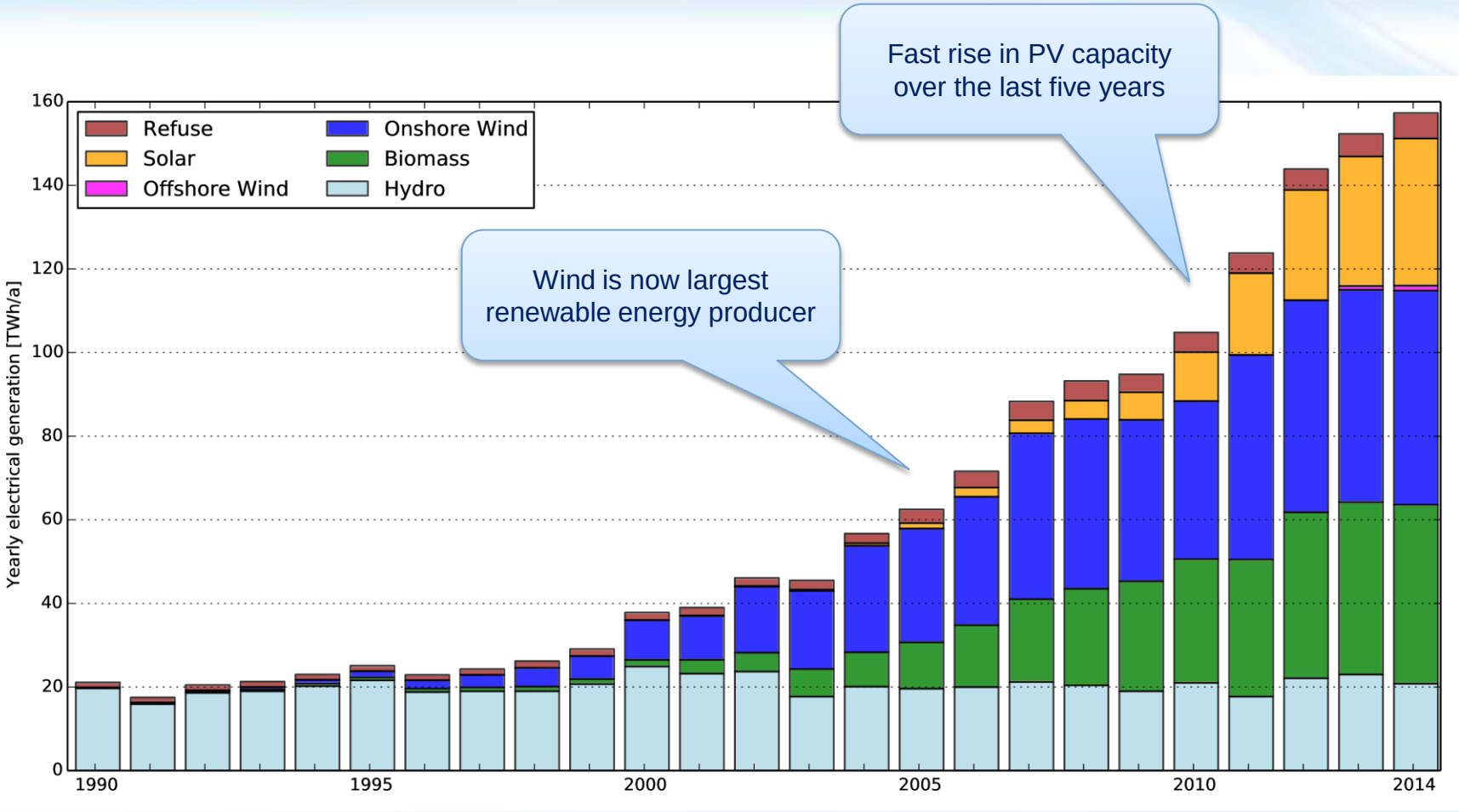
Mild winter in 2014 causes drop in demand

Brown coal production still large, despite high CO2 emissions

Renewables share rises as nuclear production drops

Source: Energynautics, based on statistics from AG Energiebilanzen e.V.

Focus on Renewables in Germany since 1990



Source: Energynautics, based on statistics from AG Energiebilanzen e.V.

Germany: Some Weeks with Less Wind and Solar...

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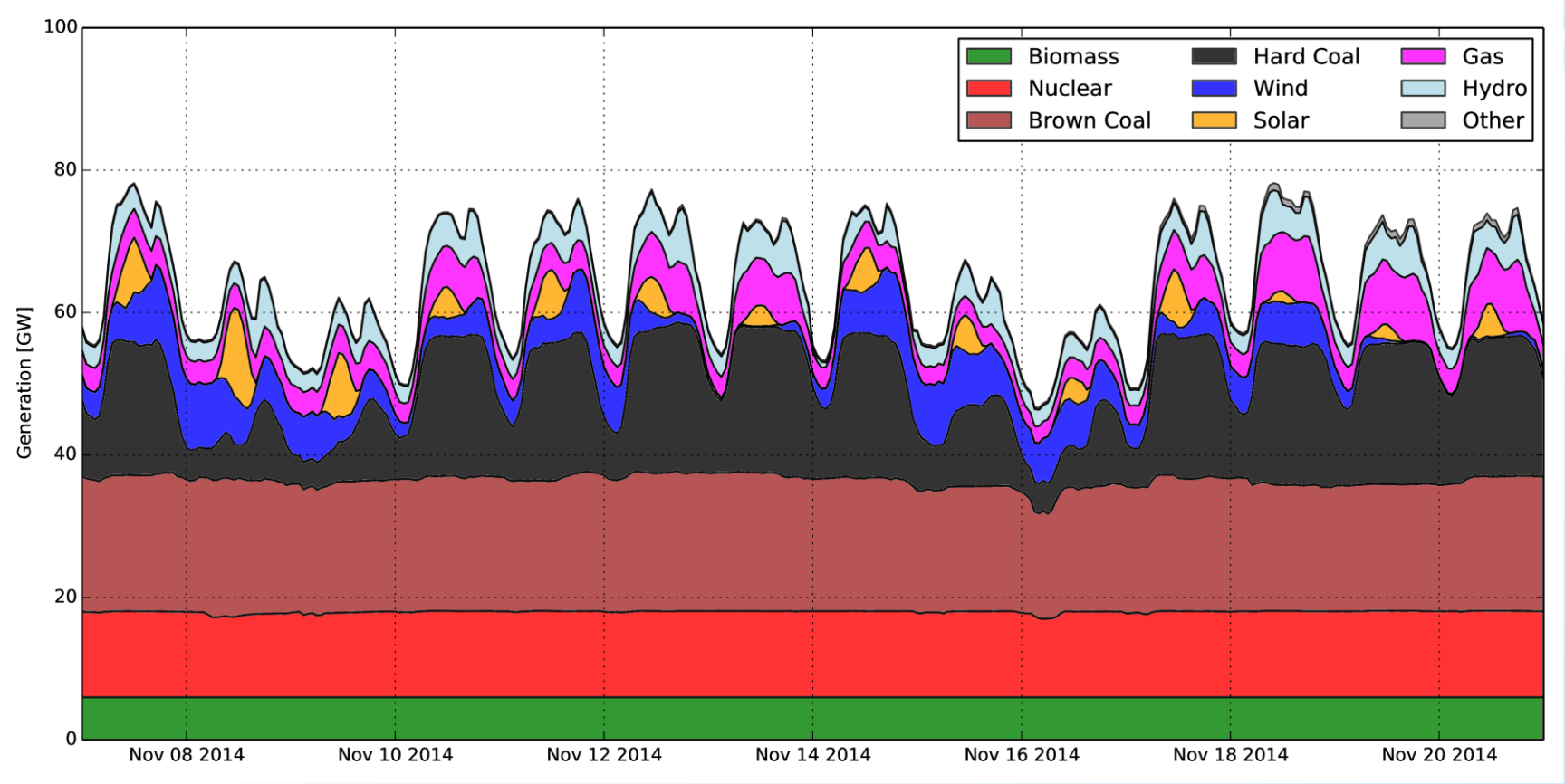

Source: based on statistics from EEX and ENTSO-E

Germany: Some Weeks with High RE Coverage

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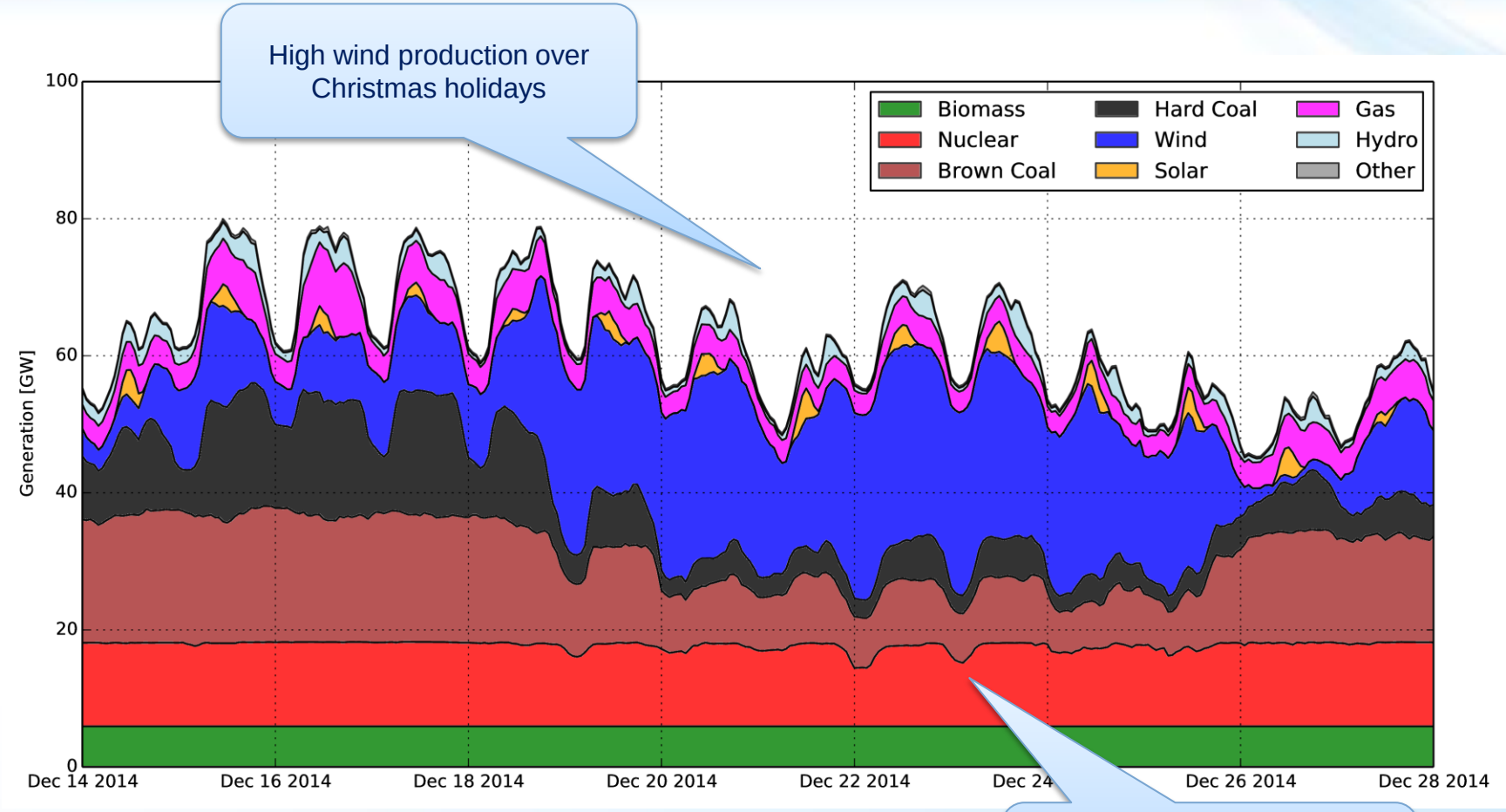
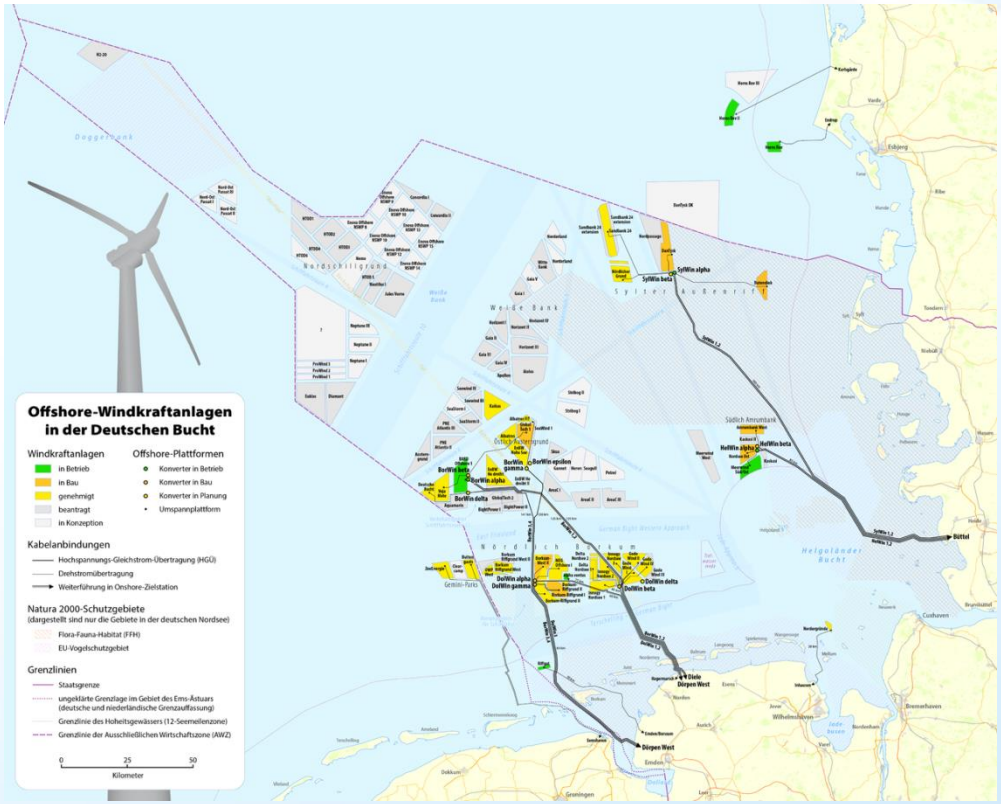


Source: based on statistics from EEX and ENTSO-E

Near-Term Outlook for Germany

Germany's Feed-In Tariff (FIT) has worked very well to encourage the growth of renewables. In the near-term we can expect:

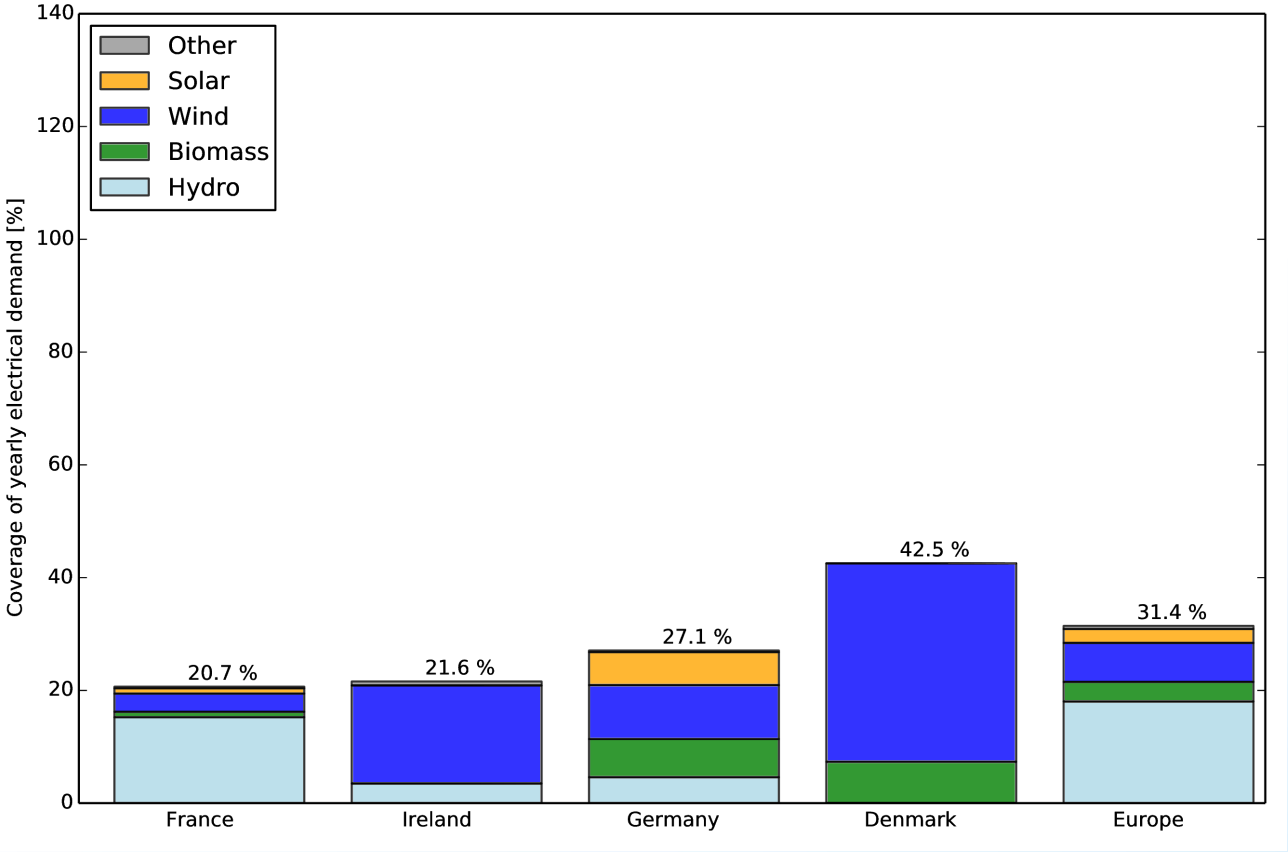
- After teething problems, 2,400 MW of **offshore wind** due online in 2015
- Currently only 0.5% of wind production lost due to **grid bottlenecks**, but this could increase as wind capacity in North increases (power needed by loads in South)
- Transmission network not being built out fast enough
- Experimental **renewable capacity auctions** may result in slower renewables growth than with FIT



Existing and planned offshore wind parks in the North Sea; source: Wikipedia

2. FUTURE EUROPEAN SCENARIO WITH 77% RENEWABLES

Jump from today's renewable shares...



...to Greenpeace pow[E]R Advanced Scenario 2030

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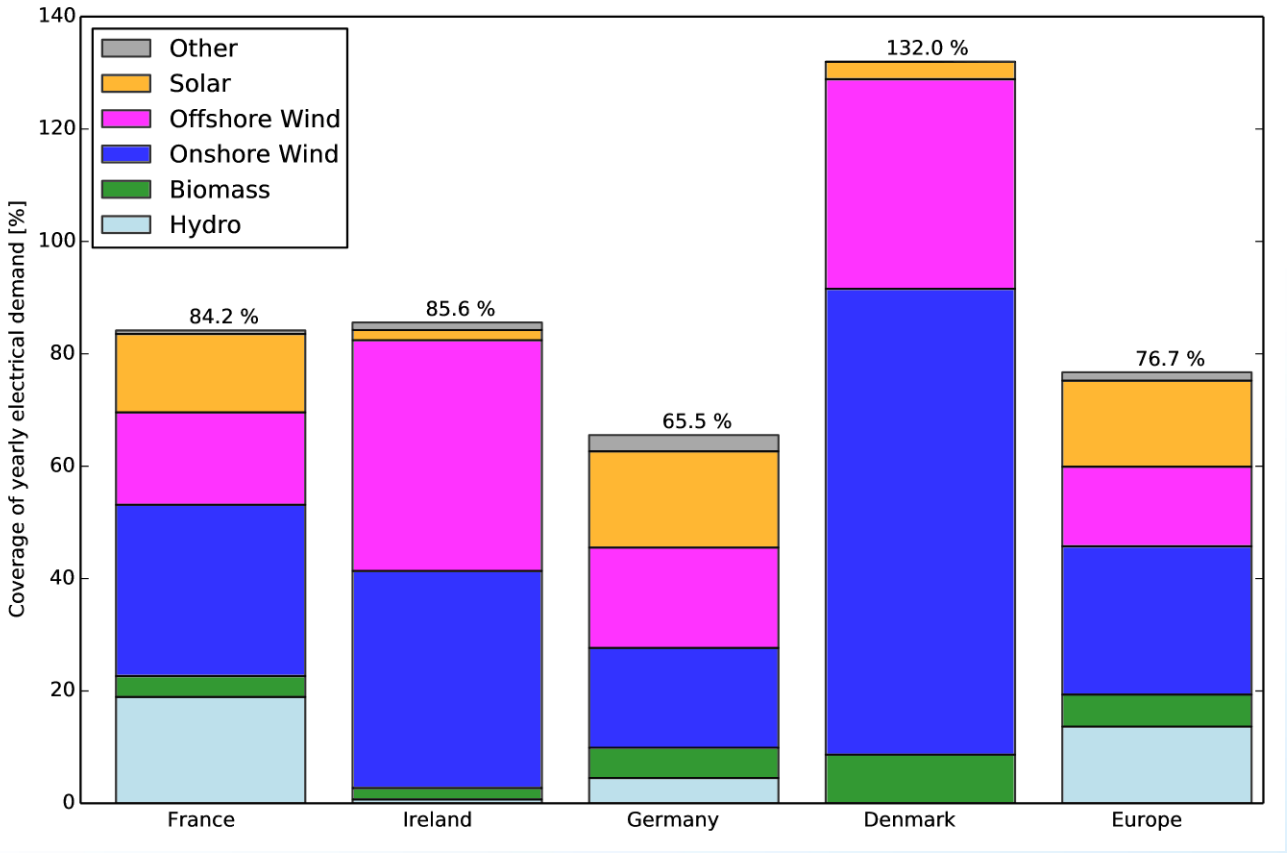

- **77% coverage of European load with renewables**
- **90 GW of PV and 64 GW of wind in Germany**
- **Big pushes for renewables in France**

Biggest system adjustment needed to accommodate this much renewables:
GRID EXTENSIONS

Smoothing effects of continental interconnection

Extending grid capacity brings big benefits for renewables:

- Connects regions with abundant renewables (e.g. solar in Spain and wind in Northern Europe) to load centres
- Leverages smoothing effects, since the bigger the area, the lower the fluctuations of wind and PV; the wind is always blowing somewhere

Energynautics' aggregated model of existing and planned high voltage grid in Europe.

Connecting Renewables to Load Centres

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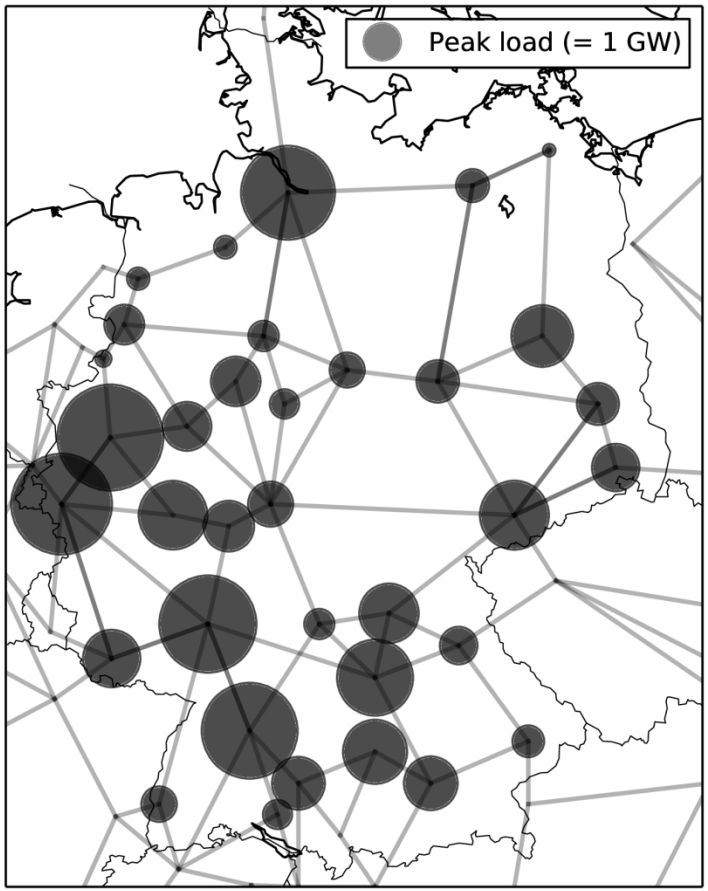
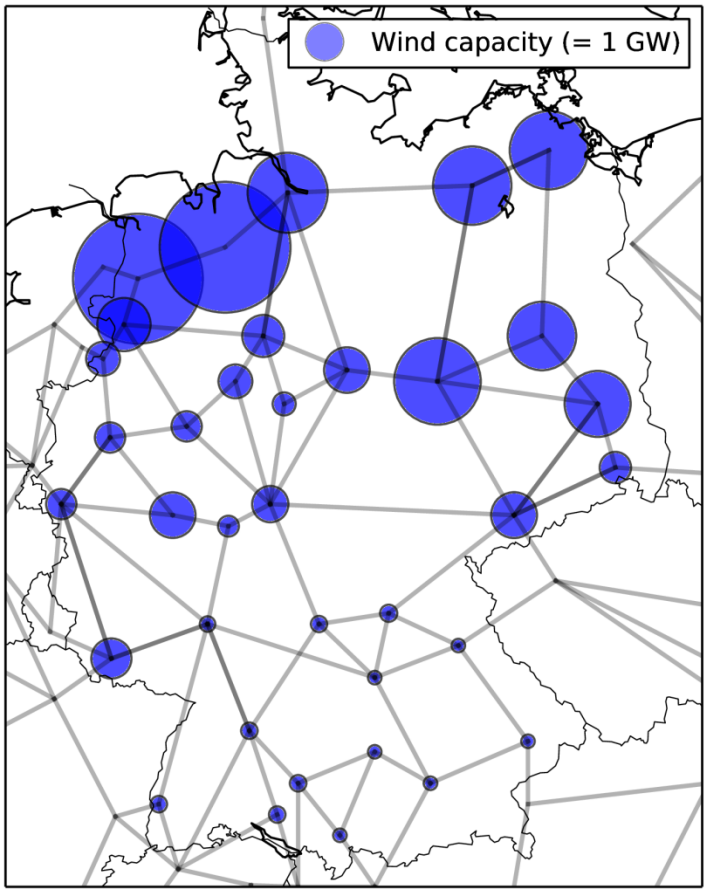
Greenpeace sees increase of wind capacity from 36 GW today to 64 GW in 2030.
But this capacity is mostly in the North, while load centres are in South and West.





Solution: connect up Europe by 2030 with High Voltage Direct Current Overlay Network

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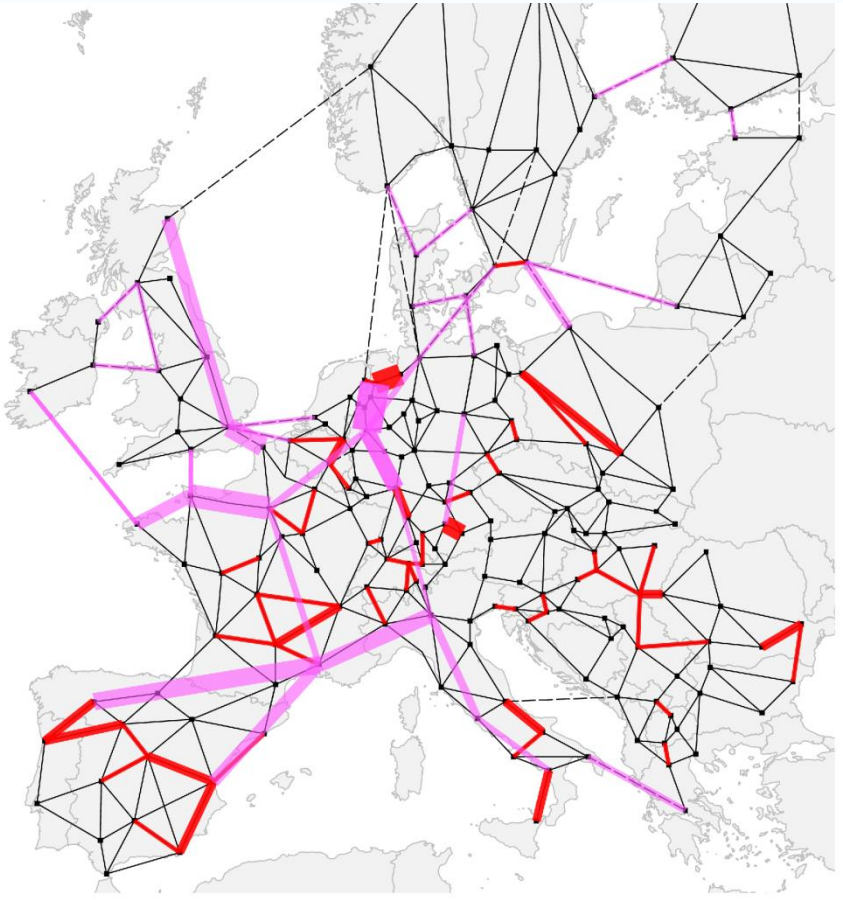


New electricity corridors (red and purple) needed by 2030 in powE[R] scenario:

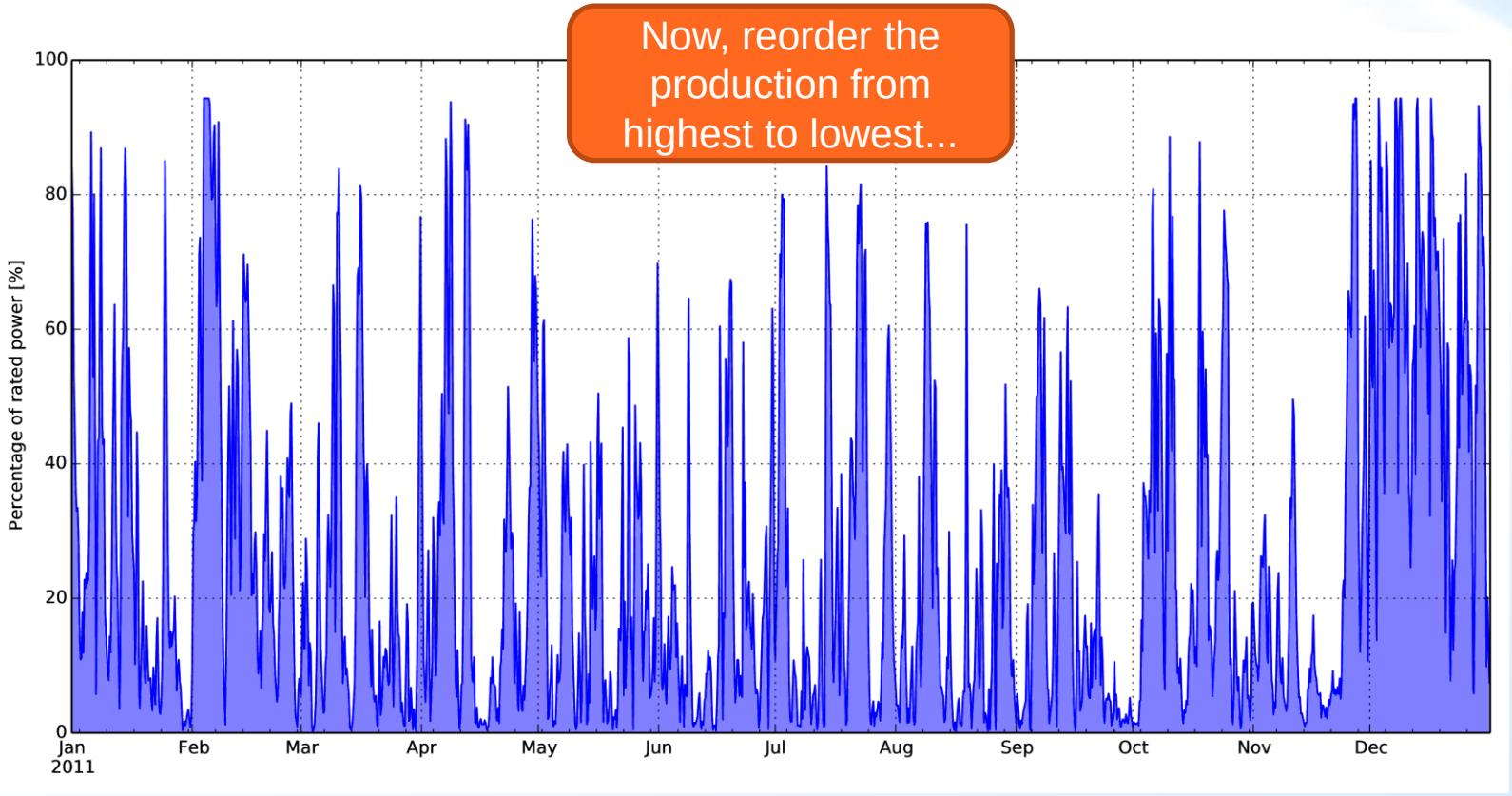
- From North-West European coastlines to central cities
- Spain and Italy up into Central Europe

HVDC provides long-distance, low-thermal-loss alternative to HVAC.

Background map made with Natural Earth. Free vector and raster map data @ naturalearthdata.com.

Smoothing benefits of interconnection

If we look at a single wind park in Germany, its production varies during the year.



Source: Energynautics, based on Reanalysis weather data.

Duration curve of a single German wind park

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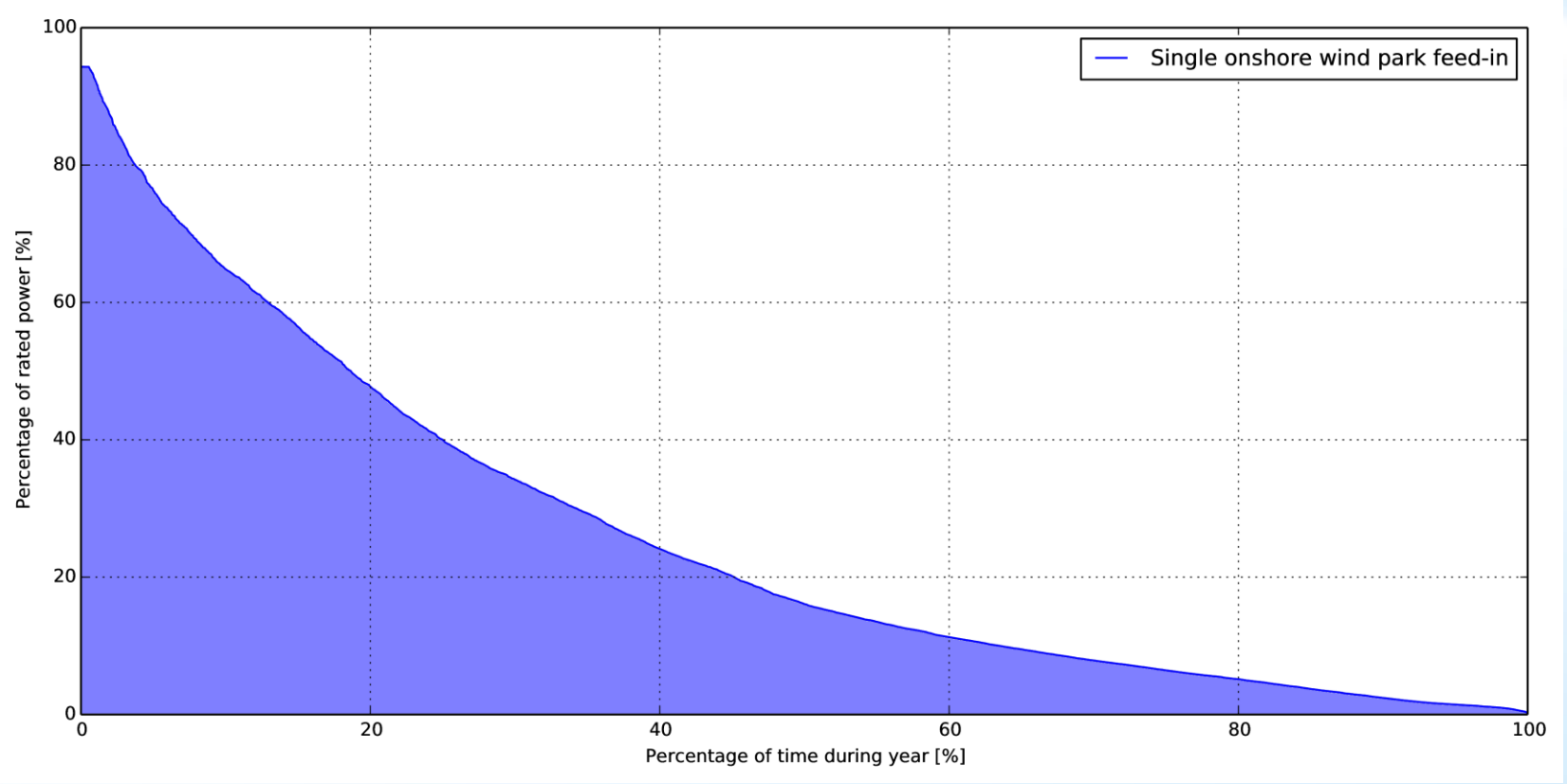
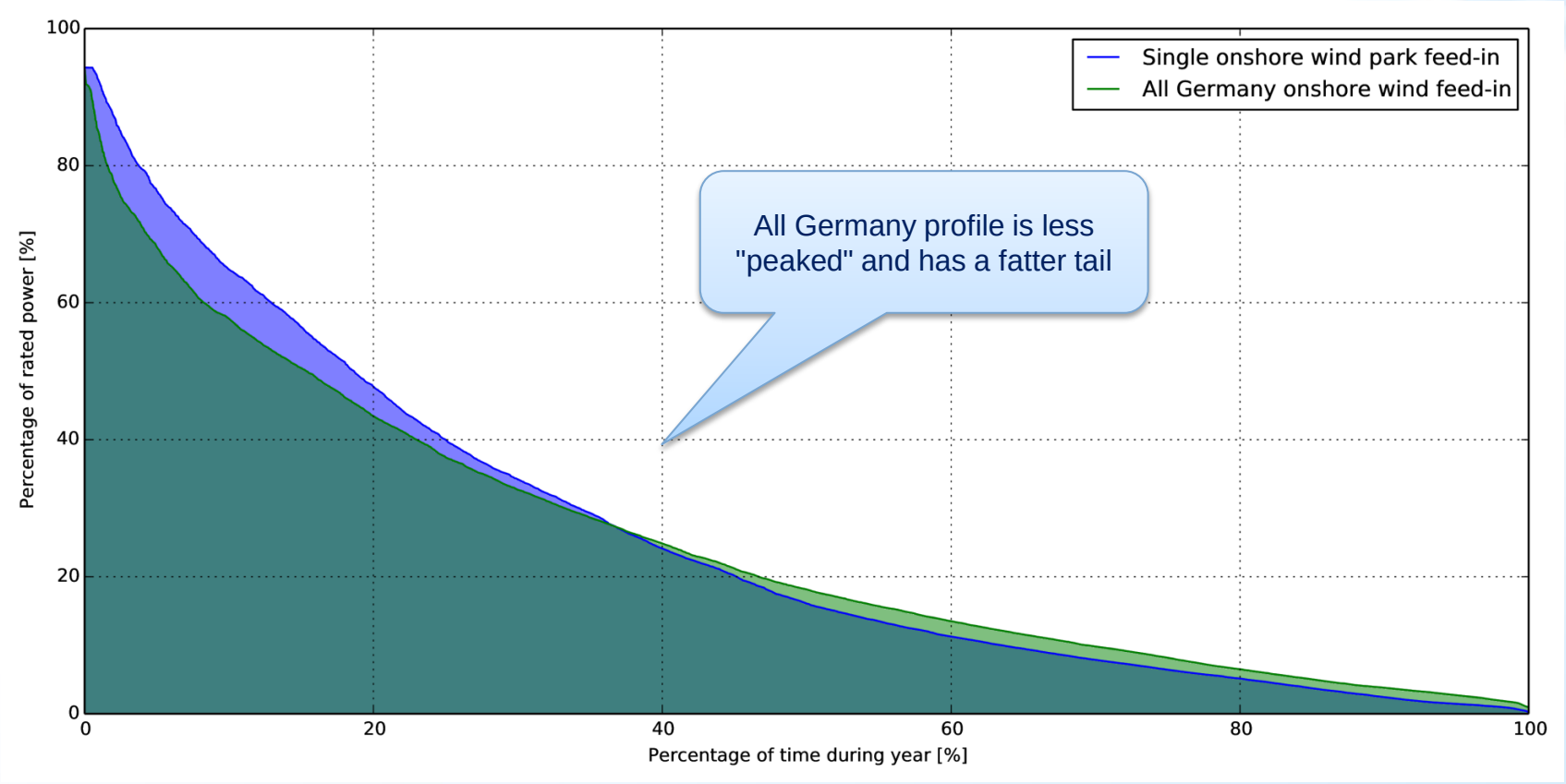
Now we're ordered high production hours to the left, low production to the right.

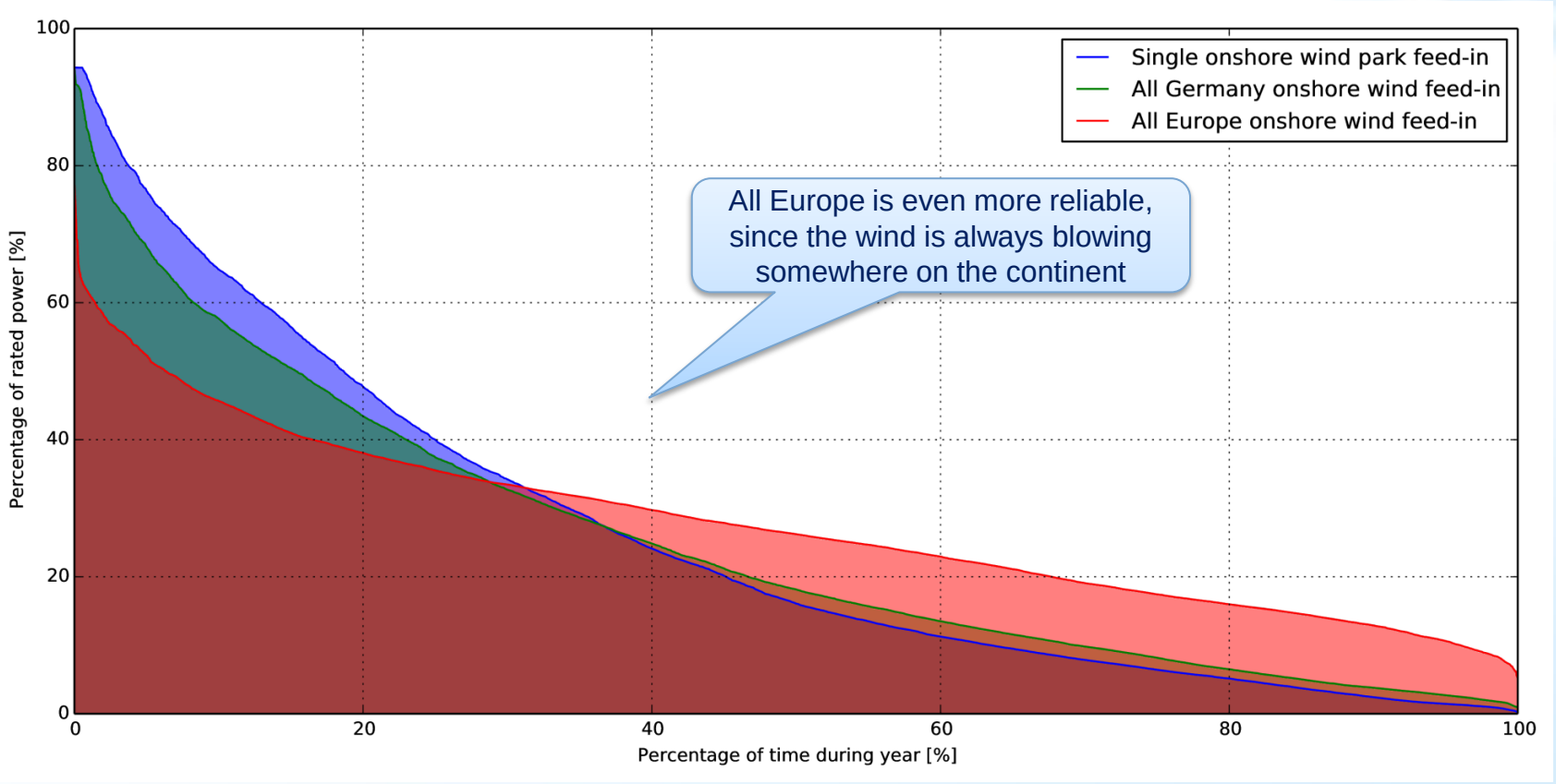


Warning: By reordering the wind production, we should not lose sight of the short-term variability of wind production, which changes from hour to hour and may require flexibility from other generators in the power system; also we should bear in mind the production relative to the load, not just the absolute production.

All onshore wind in Germany: more smoothing

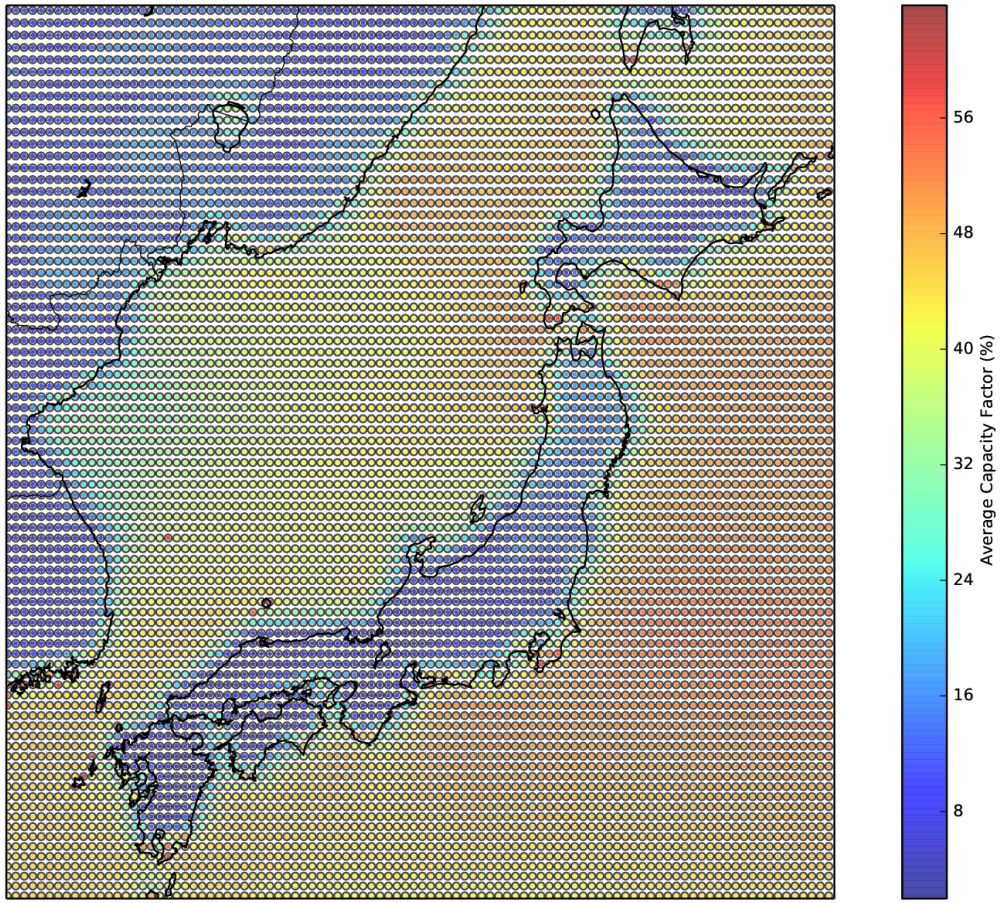


All onshore wind in Europe: excellent smoothing



3. COMPARISON WITH JAPAN

Japan's wind resources



Japan's current onshore wind capacity factor averages around 20%

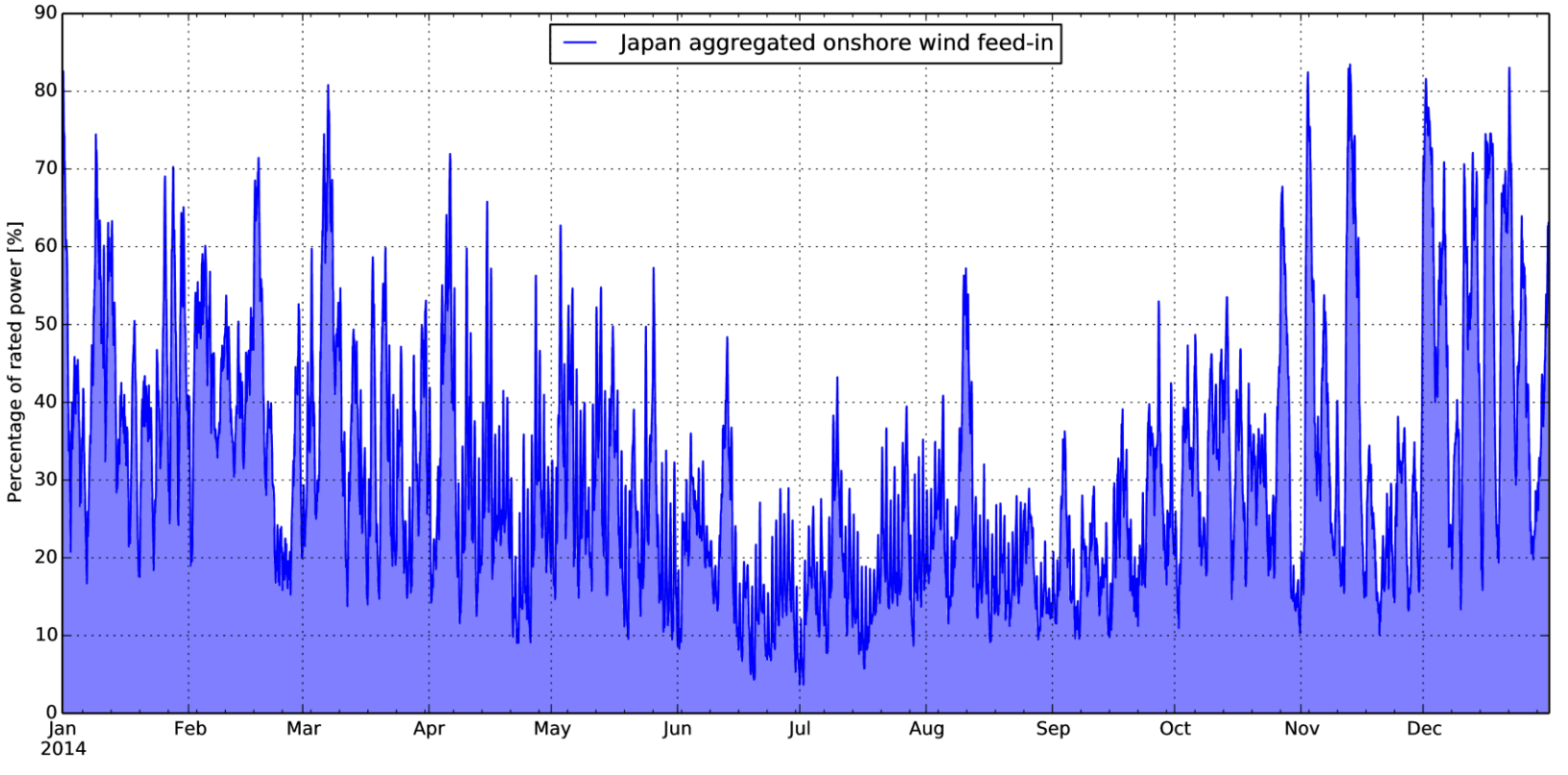
There are good sites along the coastline, which are geographically well-spread out, so good for smoothing (if there is sufficient grid capacity)

Offshore resources are even better, but seafloor gets deep quickly...

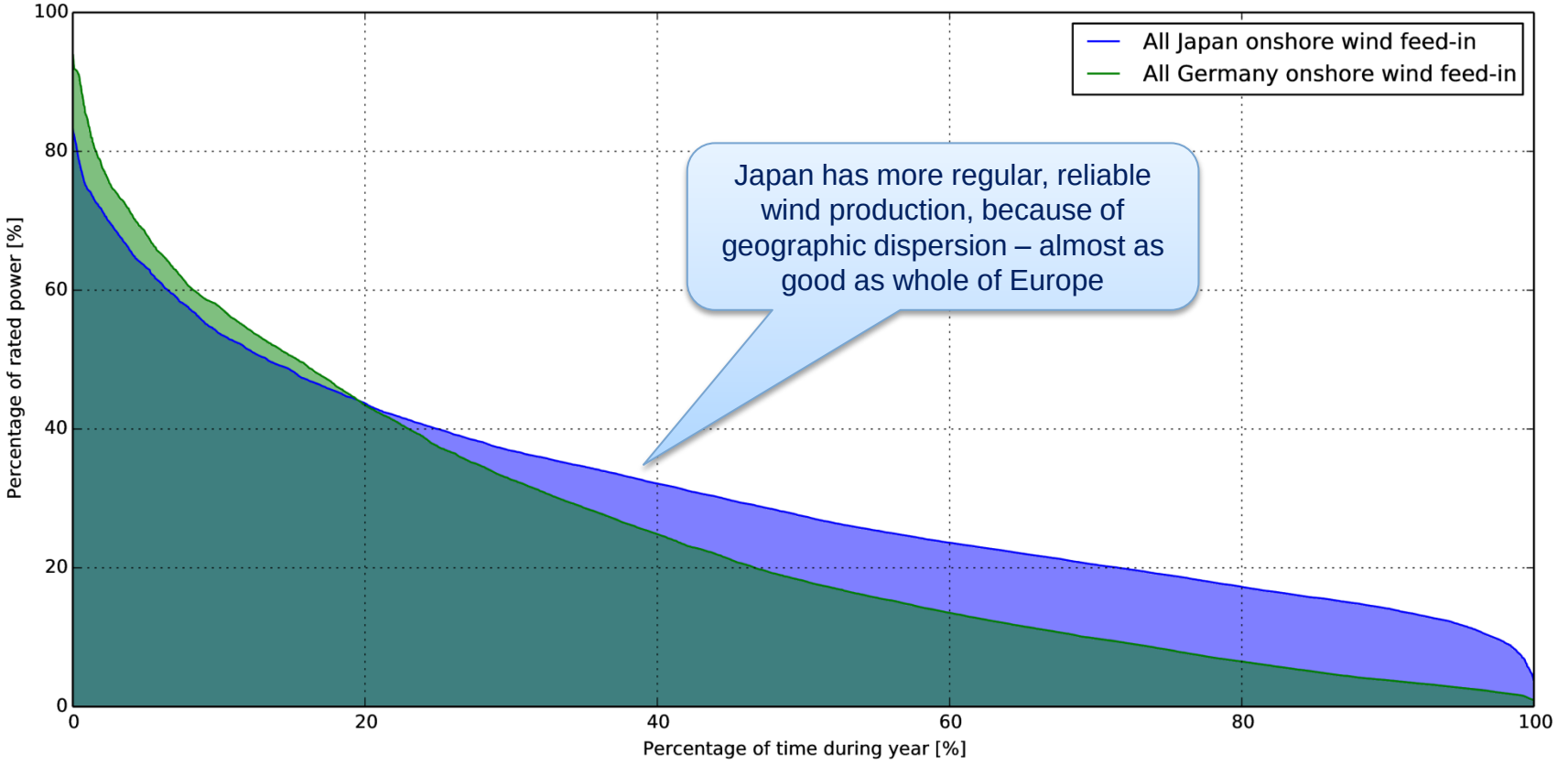
Source: Energynautics, based on National Centers for Environmental Prediction (NCEP) Climate Forecast System (CFS) Reanalysis data

Theoretical profile for all of Japan

If Japan had wind turbines on all the best onshore wind sites (above 18% capacity factor), its total production profile would have looked like this in 2014:



Japan's smoothing effect is better than Germany



Warning: This comparison is based on different wind data sets, but the overall point about the shape still holds.

Some relevant experience for Japan

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- **Feed-In Tariffs** can quickly increase the share of renewable energy in a country's power system
- European countries have already been able to integrate **up to 40% variable renewable energy** (wind and solar)
- Reaching **very high shares**, like Greenpeace's powE[R] 2030 scenario, can be achieved economically with **grid extensions**, which allow for aggregated **smoothing over large areas** (without resorting to large storage solutions)
- Japan has good wind resources, distributed over a large area – this can be leveraged for **excellent smoothing effects**, but requires more grid capacity
- **Main message: renewables benefit from grid capacity**

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THANK YOU FOR YOUR ATTENTION